Title of Investigation:

Real-Time 3-D Virtual Graphical Interface for Telerobotic Control

Principal Investigator:

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Initiation Year:

FY 2004

Aggregate Amount of Funding Authorized in FY 2003 and Earlier Years:

0

FY 2004 Authorized Funding:

$35,000

Actual or Expected Expenditure of FY 2004 Funding:

In-house: $15,000 for robot electronics and fabrication;
Grants: $20,000 to the University of Maryland, College Park

Status of Investigation at End of FY 2004:

To be continued in FY 2005 with funds remaining from FY 2004 and earlier years

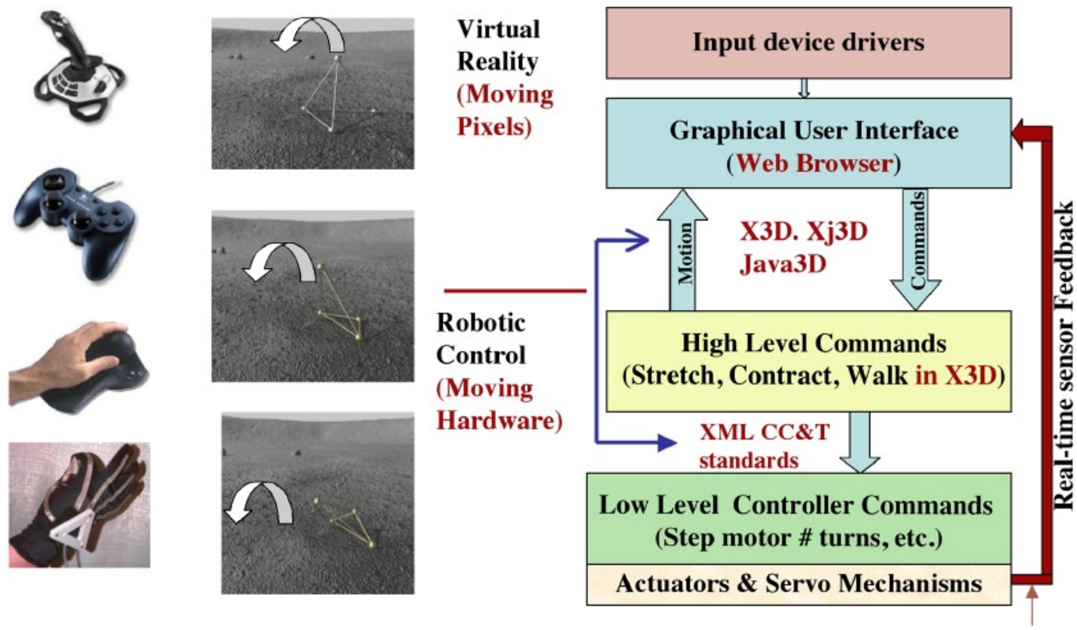
Expected Completion Date:

September 2005

Purpose of Investigation:

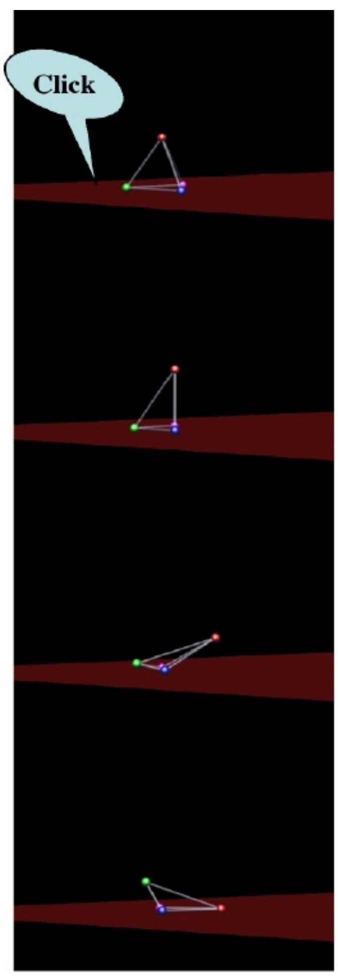
The objective of our investigation is developing a Web-based, three-dimensional (3-D) Graphical Virtual Reality (VR) interface to control a Tetrahedral Walker (TET), an innovative robotic platform developed jointly by the Goddard Space Flight Center's Codes 695 and 544 for NASA's Vision for Space Exploration initiative. We plan to control the robot's motion with a 3-D computer mouse. This interface, which features real-time 3-D imagery and other sensory feedback, is crucial for ensuring the success of future Exploration missions. Robots will be used increasingly to augment human capabilities when performing complex tasks in space, and the traditional "blind" tele-control methods might not meet mission goals because they do not take full advantage of the human ability to understand and analyze in-situ 3-D imagery in real time. Another reason for developing the VR interface is that we do not want to burden operators with the requirement that they learn customized interfaces for every robot. With the VR control system, which uses the latest Web-based, platform-independent software standards and technologies, operators will need to know only one interface.

Figure 1. System concept for a 3-D, VR Telerobotic Control Interface



FY 2004 Accomplishments:

Figure 2. One small step for a TET



There are three parts to the system design and development (Figure 1). They include the VR graphical interface; the definition of high-level commands in standard interface languages; and the integration of the interactive software to the low-level controller commands that control the TET actuators and servo mechanisms with real-time feedback.

We started by converting an X3D tetrahedron model from a Virtual Reality Markup Language (VRML) model, then designed and developed the manipulation and interaction software using kinematic-only approach coded entirely in Java 3D. We proceeded to include dynamic modeling of forces and their interactions using the free Java Astrodynamics Toolkit (JAT) (http://jat.sourceforge.net/). JAT is used in connection with Goddard research on and simulation of formation flying and neural systems control, which opens up the possibilities for cross-fertilization, new research directions, and more rapid progress through technical readiness levels (TRLs). The use of physics-based dynamics in a standards-based VR system allows the incorporation of new technologies built to those standard interfaces. For example, a VR simulation of the Goddard Exploration Test bed for Information Technology (GetIT) could be developed, tying together research using retargeted Earth science supercomputing (Beowulf) assets to develop TET Walker simulation and control and closing the loop with real-world experiments. Engineering and science processing algorithms requiring tomorrow's computing capabilities could be simulated and experimented with today, including real-time hardware-in-the-loop systems development for accelerated TRL advancement. We aim to achieve a critical mass of standards-based capability to show we have a pathway to develop advanced Exploration Initiative space systems capabilities, e.g., autonomous operations and dynamic reconfigurable structures, using high-fidelity supercomputer-based simulations.

We are in the process of adding user interactivity to the dynamic model of the TET Walker so that the user may click on any ground-node to initiate walking in the direction opposite the selected node. We also are adding the ability to pan and zoom in 3-D space to make the walking viewable from any desired perspective. When these 3-D control and navigation enhancements have been completed, we will begin the integration with the Instrument Remote Control (IRC) software that provides communications and control across a network. Using IRC the VR 3-D interface will be connected to the physical TET Walker such that the physical walker will be able to receive commands over a wireless connection from the VR user interface. The VR interface will mirror the actual steps that the physical walker performs. The integration of the dynamic force model into the Java 3-D interface is nearly complete and we soon plan to move on to constructing the IRC interface.

Planned Future Work:

The current TET command scheme has no real-time telemetry feedback (open-loop control). It relies solely on timing estimates to determine the interval to issue commands, assuming that the previous commands executed smoothly and that the TET achieved the intended configuration. In FY 2005, we plan to install position sensors (accelerometers/ potentiometers) and/or pressure sensors (e.g., load cells) on the TET struts and joints to provide feedback. The TET microprocessor will be upgraded to allow sensor interpretation in the TET nodes. The 3-D graphical control software will be modified to accommodate feedback telemetry and to reflect in real time the true configuration of the TET on the screen.

Summary:

This investigation is the first attempt to turn VR into reality. We use the latest Web-based, 3-D graphics technology to provide an intuitive human-robot interface that controls hardware in real-time. Instead of moving pixels on a screen in VR, we tele-operate hardware that in the future could be deployed millions of miles away on another planetary surface. NASA will benefit because it will reduce personnel training, operational costs, and mission risks. In addition, the program supports Goddard's participation in the NASA Astrobiology Science and Technology for Exploring Planets (ASTEP) program. Goddard currently is the lead Center in the development of command and telemetry standards that will lay the foundation for inter-robot communication. Some technical risks exist, however. The Web interface is not designed for real-time operation. The system's time-delayed performance needs to be evaluated and analyzed against mission critical tasks. Issues of live feedback from the robotic control electronics to the VR screen to reflect the true reality should be investigated in a future effort.